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A "VERTICAL" ANALYSIS OF MONETARY POLICY IN EMERGING MARKETS

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WORKING PAPER 02-16
March 2002

Room E52-251
50 Memorial Drive
Cambridge, MA 02142

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A "Vertical" Analysis of Monetary Policy in Emerging Markets

Ricardo J. Caballero Arvind Krishnamurthy*

This draft: March 8, 2002

Abstract

During emerging market crises, domestic agents might have sufficient collateral to borrow from other domestic agents, but they are unable to borrow from foreigners because the country, as a whole, lacks international collateral. In this setting, we show that an (ex-post) optimizing central bank's response to an external crisis is to tighten monetary policy to support the exchange rate. Although this response can be rationalized ex-post, it has negative ex-ante consequences when domestic financial markets are underdeveloped: It reduces the already insufficient private sector incentives to insure against external crises. If a central bank could commit, it should instead expand monetary policy. Indeed, lacking the willingness, credibility, or feasibility to implement an expansionary monetary policy during crises has important drawbacks. It means that the central bank must resort to other, potentially more costly instruments to address the underinsurance problem, such as capital controls and international liquidity requirements

JEL Codes: E0, E4, E5, F0, F3, F4, G1

Keywords: External shocks, domestic and international liquidity, monetary policy, interest parity departures, exchange rate overshooting, fear of floating, commitment, credibility, underinsurance.

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1 Introduction

This paper investigates central bank policy in an emerging economy that experiences shocks to its external supply of funds. A negative shock can lead to a crisis in which output and asset prices fall. We study central bank behavior during such a crisis and the preventive policies undertaken prior to the crisis.

The question of optimal policy during a crisis has received renewed attention in the literature (see, e.g., Furman and Stiglitz (1998), Fischer (1999), Aghion et al (2000), Cespedes et al (2000), Gertler et al (2001), and Christiano et al. (2000)). They ask, should the central bank defend the value of its currency, or should it lower interest rates? In a developed economy this question has a clear answer: the central bank will lower interest rates in a deep recession to stimulate the economy. Thus, the much debated issue should be whether the structure of emerging markets leads to a different answer.[1] That is, vis-a-vis developed economies, how does the presence of financial constraints alter the conclusion that one draws?

To answer these questions, we distinguish between developed and emerging economies by modeling the presence of two distinct financial constraints. If agents can borrow from either domestic or foreign lenders, then there are two types of financial frictions to consider: First, an agent may have limited collateral, and therefore be constrained in his borrowing from either domestic or foreign lenders. Second, the country as a whole may have limited international collateral and domestic agents thus are constrained in borrowing from foreign investors. We argue that the second type of constraint is unique to emerging markets, and is the distinguishing feature of emerging markets' crises.

When the only financial constraint faced by agents is at the micro-level, then the optimal central bank policy is to expand the money supply in order to relax the financial constraint and thus increase output. This is the recipe for a developed economy. Our model of this case corresponds closely to the standard model of microeconomic financial constraints emphasized in most of the macroeconomics literature on credit constraints (e.g., Bernanke, Gertler, and Gilchrist, 1989, and Kiyotaki and Moore, 1997). As is widely communicated in that literature, increasing the net worth of borrowers enables them to receive additional credit from either domestic or foreign lenders and thereby increases aggregate output. In our model, expanding the money supply accomplishes this task.

When the financial constraint exists at the country level, this logic fails because monetary policy only regulates the borrowing of a domestic agent from a domestic lender. As

[1] This question has not found a clear answer from either academics or policy-makers. See, e.g., Boorman et al (2000) for a survey of the —often contradictory— arguments and empirical evidence.

long as the marginal lender is another domestic agent, monetary injections increase output. However, when the marginal lender is a foreign investor, monetary policy is ineffective because it does not alter the international collateral of the country.[2,3]

This distinction between domestic borrowing capacity (domestic liquidity) and international borrowing capacity (international liquidity) is the central theme in our analysis. In an emerging market crisis the international liquidity of the country is limited relative to its investment needs. The supply of international funds is fixed and price-inelastic ("vertical"). In Section 2 we develop a dual-liquidity model in which a shock may lead to a binding vertical constraint. We show that asset prices, the exchange rate, and output fall during such an event. We also contrast that model with one in which there is no distinction between domestic and international liquidity.

Section 3 describes the objectives of the central bank and derives central bank policy during a crisis. Although monetary expansions have no output effects in our model, they have large effects on the exchange rate. Since the quantity of international funds is inelastic, its price —the exchange rate— is very responsive to monetary policy. A central bank that is trading-off output and an inflation target will see little benefit by expanding, and significant inflation-target benefits by contracting. Thus the model rationalizes the observed tendency of central banks to tighten monetary policy during external crises, regardless of the prevailing exchange rate system. (See Calvo and Reinhart (2000) and Hausmann et al (2001) for extensive documentation of "fear-of-floating" among emerging economies with flexible exchange rate regimes.)

In Section 4 we turn to ex-ante optimal (preventive) policies. That is, we shift our attention to the time prior to the crisis, when private sector and central bank actions could lessen the extent of the coming crisis. As in Kydland and Prescott's (1977) and, Barro and Gordon's (1983) analysis, we find that the interplay between private sector expectations and central bank actions creates a need for commitment. However, the concern in our model is with the private sector's preventive measures rather than with its inflation expectations.[4] In

[2] Chistiano et al (2000) address issues similar to those of our crisis monetary policy analysis. In their model, imperfect liquidity substitution stems from imperfect input-substitution, and from the fact that different inputs are paid in different currencies.

[3] While in very different terms, Dornbusch (2001) also expresses his uneasiness about the assumption that emerging economies with access to monetary policy can use it to boost activity. For example, in criticizing the standard view, he writes: "The loss of the lender of last resort [argument] is intriguing. This argument is based on the assumption that the central bank – rather than the treasury or the world capital market – is the appropriate lender..."

[4] See Part V in Persson and Tabellini (2000) for a thorough review of the inflation-credibility literature. Also, see Chapter 9 in Obstfeld and Rogoff (1996) for an emphasis on open economy implications of inflation-

our model of emerging markets, the private sector will underinsure against crisis events (see Caballero and Krishnamurthy, 2001a). Moreover, the extent of the underinsurance depends on the expectations over central bank actions during a crisis. We show that the strategy of squeezing domestic credit during crises lowers the private return to taking preventive measures and hence discourages it. As a result, it is optimal for the central bank to commit to counter-cyclical monetary policy.

Our analysis links the extent of the underinsurance problem and the value of monetary policy as an incentive instrument to the degree of domestic financial development, the degree of commitment to a countercyclical monetary policy rule, and to the credibility of the country's post-crisis inflation target.

The counter-cyclical monetary policy recommendation highlights an unusual commitment problem, because a central bank's ex-post optimal response will be to support the exchange rate by contracting monetary policy. This observation takes us to another normative point. In Section 5, we show that our framework offers a solution in the instances in which the ex-ante optimal strategy is not credible or feasible. Since the primary problem is one of underinsurance, either direct or indirect ex-ante measures that induce the private sector to carry more international liquidity into crisis states will reduce the problem. Taxation of capital inflows, international liquidity requirements, or large sterilizations of capital inflows are examples of these measures. While enacting the measures may be costly, they should be seen as the costs of having lost the ability to use monetary policy in an environment of recurrent external crises.

2 The Private Sector and Crises

This section lays out a model of the private sector and financial crises based on Caballero and Krishnamurthy (2001a). Firms hold liquidity in order to meet financial needs that may arise before their projects are completed. This liquidity may be held either as domestic or international assets. In the vertical view of this paper, the distinction between these two forms of liquidity is central for aggregate outcomes. We contrast this view with a horizontal view in which the distinction is immaterial for outcomes.

2.1 Setup

We study an economy exposed to an external financial crisis. The crisis occurs at date 1, and is followed by a final date 2 when firms repay their outstanding debts. We start time

credibility considerations.

with a date 0, which is a fully flexible period when agents make investment and financing decisions. The periods are indexed by $t = 0, 1, 2$, and there is a single (tradeable) good.[5]

There is a unit measure of domestic firms that each have access to a production technology. Building a plant of size k at date 0 requires them to invest $c(k)$ — with $c(.) \geq 0$, $c' > 0$ and $c'' > 0$ — which yields date 2 output proportional to the size of the plant (see below). Domestic firms have no resources at date 0. They must import the capital goods and borrow from foreigners to finance their investment. The financing and investment decisions maximize expected plant profits at date 2. Each firm is run by a domestic entrepreneur/manager who has risk neutral preferences for date 2 consumption of the single good.

Domestic firms face significant financial constraints. Each firm is endowed with w units of collateral, in the form of receivables arriving at date 2. Only claims against these date 2 goods have collateral value to foreigners (e.g., prime exports). We disregard explicit equilibrium default and assume that all financing is done via fully collateralized debt contracts. At date 0, when firms sign debt contracts with foreigners, the contracted repayments of f must not exceed w. Foreigners lend against this collateral at dates 0 and 1 at the rate i_0^* and i_1^* from period 0 to 1, and 1 to 2, respectively.

2.2 Date 1 Financing Needs and Crises

For the remainder of this and the next section, let us take as given all date 0 investment and financing decisions and focus on the crisis period. In a crisis, the financial constraints bind for firms.

There are two (aggregate) states of the world at date 1, $\omega \in \{b, g\}$, which occur with probabilities $\{\pi, 1 - \pi\}$. In the b-state, firms may receive a liquidity shock for which they need resources. Financial constraints will prevent them from fully absorbing the liquidity shock. The b-state is the crisis state. In contrast, in the g-state there are no shocks and financial constraints do not bind. Let us now turn to defining the shock in the b-state, and explaining how financial constraints may come to bind.

The plants of one-half of the firms receive a shock at date 1 that lowers output per plant from A to a. The shock only arrives in the b-state, but is idiosyncratic in that each firm receives the shock with probability 0.5.[6]

[5] See Caballero and Krishnamurthy (2002) for a model which builds on the distinction between nontradable and tradable goods. While this distinction is realistic and makes some of our results a bit less stark, it is qualitatively unimportant for the issues we discuss here.

[6] More realistically, we can introduce the aggregate shock as a contraction of international collateral (e.g., due to a decline in terms of trade) or through a rise in the international interest rate faced by the country's

The productivity decline can be offset by reinvesting θk ($\theta \leq 1$) goods, to give date 2 output of,

$$\tilde{A}(\theta)k = (a + \theta\Delta)k \leq Ak, \qquad \text{where} \qquad \Delta \equiv A - a.$$

We assume that the return on reinvestment exceeds the international interest rate:

$$\Delta - 1 > i_1^*.$$

This means that firms will borrow as much as possible to finance reinvestment. A crisis occurs if firms are curtailed in their date 1 reinvestment, $\theta < 1$, despite the fact that $\Delta - 1 > i_1^*$. In this case firms are financially constrained at date 1. Parameter assumptions ensure that this occurs in equilibrium only in the *b*-state (see the appendix).

A firm that receives a liquidity shock is termed **distressed**. To cope with the shock, the firm first borrows against its net international collateral,

$$w^n \equiv w - f$$

directly from foreigners. After this, it must turn for funds to the domestic firms that did not receive a shock (termed **intact**). Intact firms have no output at date 1 either, so they must borrow from foreigners if they are to finance the distressed firms. They can do this up to w^n. But why would intact firms lend to distressed firms any more than foreigners would? That is, why is the domestic financial market different from the international financial market? Because we assume that domestic agents accept the output from a firm's plants as collateral.

However, since a perfectly functioning domestic financial market is hardly a good description of an emerging economy, and because this departure has central implications for our analysis, we assume that only a fraction of the output from the plants can be pledged to other domestic agents. We make this fraction equal to the minimum output, ak. Since firms can use this collateral to borrow up to this amount, we refer to ak as domestic liquidity. Likewise, since at date 1 firms can borrow from foreigners up to w^n of international collateral, we refer to w^n as the international liquidity during the crisis.

2.3 The Horizontal View

In the horizontal view, distressed firms are constrained in meeting their financing needs only to the extent that they have limited liquidity. Their total liquidity of $ak + w^n$ is insufficient to meet the production shock.

prime borrowers (see Caballero and Krishnamurthy, 2001a). In this case, for the crisis to occur only in the *b*-state we would have to add an incomplete international insurance markets assumption (as opposed to the technological assumption of liquidity shocks that we made). Our conclusions would be similar.

Translated into our context, the horizontal view implicitly assumes that the country as a whole, at the margin, has an international liquidity slack. A foreigner would be willing to extend another loan at i_1^* to some domestic firm. But the worthy firm is not distressed. The shortfall is in the total liquidity held by distressed firms, rather than in the country's international liquidity.

In our model, because intact firms borrow from foreigners against w^n and lend to distressed firms against ak, there is excess international liquidity if,

$$\frac{1}{2}w^n > \frac{1}{2}ak. \tag{1}$$

Since the international financial constraint is not binding for intact firms, the interest rate they charge on the loan to a distressed firm against domestic collateral, is determined by the arbitrage condition:

$$i_1^d = i_1^*.$$

Total reinvestment is then determined by the individual firms' financial constraints:

$$\theta^H k = \frac{w^n + ak}{1 + i_1^*} < \frac{2w^n}{1 + i_1^*}, \qquad \theta^H < 1, \tag{2}$$

where the superscript H denotes the horizontal equilibrium. The first inequality shows that the economy has not used all its international liquidity, while $\theta^H < 1$ indicates that the economy is in a crisis: distressed firms are unable to meet all financing needs because of their binding financial constraints.

We refer to this as the horizontal view, because the price of loans is not affected by their quantity. A distressed firm in principle could continue borrowing at the given interest rate i_1^*, as long as its *domestic* financial constraint was relaxed.

2.4 The Vertical View

In this view, the international supply of funds faced by emerging economies during external crises is vertical. The main problem for the country is not insufficient liquidity of distressed firms, but rather a shortage of country-wide international liquidity. Inequality (1) is reversed:

$$\frac{1}{2}w^n < \frac{1}{2}ak,$$

so that distressed firms have enough domestic liquidity to pay for the international liquidity of the intact firms. However, international liquidity is scarce relative to the financing need:

$$\frac{k}{2} > \frac{w^n}{1 + i_1^*}.$$

Since all investment at date 1 is eventually financed by foreigners, the stock of international liquidity is all that determines investment in this region:

$$\theta^V k = \frac{2w^n}{1+i_1^*}, \tag{3}$$

where the superscript V stands for vertical equilibrium. Note that domestic liquidity does not appear at all in this expression.

In the vertical modeling of crises, the interest rate on loans against domestic collateral departs from i_1^*. Since intact firms are borrowing up to their maximum capacity from foreigners and lending to distressed firms against domestic collateral, the domestic price of a dollar-loan, i_1^d, rises above i_1^*:

$$i_1^d > i_1^*.$$

In equilibrium, loans collateralized by w are made at rate i_1^*, while those collateralized by ak are made at the higher rate of i_1^d.

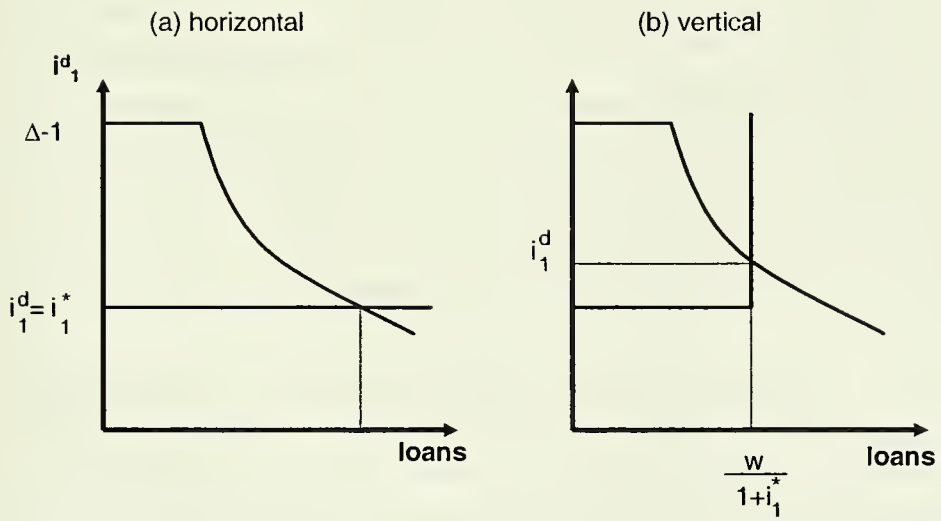

Figure 1: Equilibrium in the domestic loans market

Figure 1 represents the equilibrium determination of i_1^d. The vertical axis is the price, i_1^d, while the horizontal axis measures domestic loans or domestic reinvestment. For $i_1^d = i_1^*$,

intact firms elastically supply their international liquidity to distressed firms. However, at the point $w^n/(1+i_1^*)$, intact firms run out of international liquidity, and the supply curve turns vertical. On the other side of the domestic financial market, the demand for funds by distressed firms turns downward sloping when the domestic collateral discounted at $\Delta - 1$ is insufficient, and hence effective loan demand is: $ak/(1+i_1^d)$. The figure represents two cases: one equilibrium in the horizontal region (panel a) and one in the vertical case (panel b).

The figure illustrates how i_1^d rises above i_1^* in the vertical region. Note also that i_1^d can never exceed $\Delta - 1$. This is because the marginal product of reinvestment for distressed firms is $\Delta - 1$, and as a result distressed firms will never pay more than $\Delta - 1$ for funds.

However, there is a large interval for demand within which i_1^d lies strictly between i_1^* and $\Delta - 1$. In this case,

$$i_1^d = \frac{ak}{w^n/(1+i_1^*)} - 1 > i_1^*. \tag{4}$$

While a change in domestic liquidity has no effect on output in equilibrium, it does have a direct effect on i_1^d as long as the economy suffers from shortages in both forms of liquidity (point A in Figure 2). A deficit of international liquidity implies that $i_1^d > i_1^*$, and a shortage of domestic liquidity implies that the cost of capital will generally be less than the marginal product of investment at date 1, $i_1^d < \Delta - 1$. Changes in the relative amount of these liquidities affect i_1^d in this region.

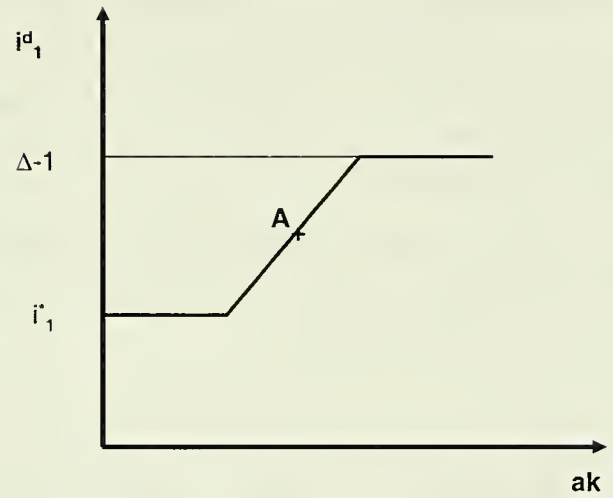

Figure 2: Equilibrium domestic dollar rate

The only equilibrium price in our model is i_1^d. This is the interest rate at date 1 on a risk free one-period loan against a unit of domestic collateral, and is both the dollar cost of capital for firms in need of funds, and the expected return on loans for domestic lenders.

Less international liquidity (w^n) leads to a higher i_1^d. The rise in this interest rate also means a fall in the date 1 value of domestic collateral ($\frac{ak}{1+i_1^d}$).

3 Discretionary Monetary Policy during Crises

The central bank affects the economy through monetary injections at date 1. Money is distributed as "helicopter" drops to firms, and redeemed at date 2 with taxes collected by the government.

We do not provide a detailed description of the government's tax powers and its tax base. Instead we assume that the government collects T goods via non-distortionary taxation, and that these taxes do not come from firms. We think of these taxes as resources from a consumer sector that has a date 2 endowment of $y^c \geq T$. When it is effective, expansionary monetary policy will transfer resources from consumers to the corporate sector. We focus on

the limit, "no-monetary-frictions" case, because our qualitative conclusions do not depend on the presence of such frictions.[7]

As in Woodford (1990) and Holmstrom and Tirole (1998), we propose a mechanism that gives the government a special power —beyond that of the private sector— to create liquidity. However, in our setup, this does not immediately translate into a government tool for increasing output. We assume that taxation used to fund a monetary expansion does not alter the international collateral of the country. Foreign investors continue to lend only against w, and the extent of a crisis is still determined only by w^n. Thus, the goods that back the money supply are not seen as international collateral, and monetary injections during crises only add to firms' domestic liquidity.

3.1 Central Bank Objectives and (inflation-target) Credibility

At the beginning of date 1, the central bank has $\underline{M}$ outstanding that is held by firms. If it does not inject any more money, it redeems $\underline{M}$ at date 2 with planned taxes of $\underline{T}$, giving an exchange rate (price level) of:

$$e_2 = \frac{\underline{M}}{\underline{T}}.$$

We normalize this no-intervention exchange rate to one, so that $\underline{M} = \underline{T}$.

The central bank may intervene by injecting $M - \underline{M}$ more money into firms. The effectiveness of this intervention depends on credibility. We introduce (inflation-target) credibility considerations into monetary policy by assuming that tax revenues are uncertain.

There are two polar states of the (tax) world realized at date 2: In the high tax revenue state the central bank has enough tax base to redeem all of its money and maintain the price level of one ($e_2^{HIGHTAX} = 1$). In the low tax revenue state, the central bank's tax base is only $\underline{T}$ and the exchange rate must depreciate if M exceeds $\underline{M}$. Thus,

$$e_2^{LOWTAX} = \max\left[1, \frac{M}{T}\right], \quad T \leq \underline{T}.$$

The reason we have used the max operator is that it is possible that the central bank chooses $M < \underline{M}$, in which case it removes money from the economy. In a growing economy, this can be viewed as a lower rate of money growth. If $M < \underline{M}$, we assume that government also reduces taxes collected on date 2 so that the date 2 exchange rate remains at one. There is nothing at stake in making this assumption, as opposed to the assumption that tax revenues are independent of M.

[7] See Diamond and Rajan (2001) and Lorenzoni (2001) for liquidity models of the banking system and the role of monetary policy in it.

The tax-states occur with probability p (high tax revenue) and $1-p$. Since a central bank with a larger tax base will be able to inject more money without creating inflation at date 2, credibility is increasing in p. That is, the higher p is, the lower the expected depreciation of e_2 in response to a monetary injection is.

The central bank has no reason to inject money at date 1 in the g-state. Thus,

$$e_2^g = 1, \qquad e_1^g = 1 + i_1^*, \tag{5}$$

where the expression for e_1^g follows from a standard interest parity condition.

In the b-state, the central bank injects $M - \underline{M}$ into firms, and

$$e_2^b = \max\left[1, \frac{M}{T}\right], \quad T \leq \underline{T}. \tag{6}$$

The central bank takes as its objective the maximization of aggregate consumption minus an inflation cost. In our context, the cost term is a quadratic loss function of the exchange rate as it depreciates from e_1^g:[8]

$$\Pi^{cost}(e_1) = \frac{\alpha}{2}\left(\frac{e_1}{e_1^g} - 1\right)^2 \qquad \alpha > 0. \tag{7}$$

3.2 Domestic Liquidity and the Interest Parity Condition

Post-injection, a distressed firm has domestic liquidity totalling,

$$ak + E\left[\frac{M}{e_2}\right],$$

where the expectation is taken over the realizations of the tax base at date 2. In equilibrium, this domestic liquidity is exchanged for:

$$\frac{ak + E[M/e_2]}{1 + i_1^d} \tag{8}$$

units of international liquidity.

For an intact firm to be willing to exchange a unit of international liquidity for a unit of money, it must expect a return on purchasing currency equal to the domestic dollar rate, i_1^d. Thus, the expected appreciation of the currency must equal i_1^d, which is reflected in the *domestic* interest parity condition:

$$e_1 = (1 + i_1^d)\left(E\left[\frac{1}{e_2}\right]\right)^{-1}. \tag{9}$$

[8] Adding an extra cost term related to missing the date 2 target is redundant since e_2 is contained in e_1 through the interest parity condition.

The condition differs from the usual one in that there is no domestic interest rate (or equivalently, the domestic interest rate is zero). Adding a monetary friction would result in a "money demand" and introduce a domestic interest rate into this condition, but it would not add any substantive element to our discussion.

For a fixed value of e_2, a rise in i_1^d leads to depreciation of the date 1 exchange rate.

3.3 Horizontal View

Distressed firms borrow $w^n/(1+i_1^*)$ directly from foreigners and

$$\frac{ak + \mathrm{E}[M/e_2]}{1+i_1^*}$$

from intact firms. The gross output per unit of this investment is Δ. Adding this output to the output generated by date 0 investments and the consumers' endowment yields an aggregate consumption by domestic agents in the horizontal region of:

$$C^H = \left(\frac{A+a}{2}\right)k + \frac{w^n}{2}\left(\frac{\Delta}{1+i_1^*}+1\right) + \frac{ak+E[M/e_2]}{2}\left(\frac{\Delta}{1+i_1^*}-1\right) + y^c. \tag{10}$$

The object involving $E[M/e_2]$ is of interest in this expression. Using the interest parity condition from (9), we can write this in terms of e_1:

$$\frac{M}{e_1}\frac{\Delta-(1+i_1^*)}{2} > 0.$$

It follows that *output is increasing with respect to real balances.*

The next step in understanding the impact of monetary policy is to connect (nominal) money injections to real balances. Given a money stock of M, the date 2 exchange rate is:

$$e_2^b \in \left\{1, \max\left[1, \frac{M}{T}\right]\right\}.$$

Note that a choice of M greater than $\underline{T}$ results in $e_2^b > 1$ if the low revenue occurs. Since the inflation cost is minimized when $e_2^b = 1$, the central bank always uses all of its taxes to redeem money as long as $e_2^b > 1$ (see (7) and (5)). Thus, e_2^b is either one or $\max\{1, M/\underline{M}\}$, and by the interest parity condition, the date 1 exchange rate is:

$$e_1^b = \frac{1+i_1^*}{\gamma(M;p)}, \qquad \gamma(M;p) \equiv \left(p + (1-p)\min\left[1, \frac{\underline{M}}{M}\right]\right). \tag{11}$$

It follows that,

$$\frac{M}{e_1^b} = M\gamma(M;p)\frac{1}{1+i_1^*}. \tag{12}$$

The term $\gamma(M;p)$ is always less than or equal to one. It is increasing weakly in p and decreasing weakly in M. When multiplied by M, it measures the effectiveness of money

injections in raising real balances. At one extreme, a central bank with no-credibility ($p = 0$) finds that $M\gamma = \min\{M, \underline{M}\}$. Money injections have no real effect when $M > \underline{M}$. At the other extreme, a fully credible central bank ($p = 1$) finds that $M\gamma = M$. Thus, money injections raise real balances one-for-one.

Differentiating C^H with respect to M, we obtain the benefit of money injections:

$$\frac{\partial C^H}{\partial M} = \left(\frac{\Delta - (1 + i_1^*)}{2(1 + i_1^*)}\right) \gamma(M, p)\,(1 - \epsilon_{\gamma,M})\,, \tag{13}$$

where the term in parentheses is one minus the elasticity of γ with respect to M:

$$\epsilon_{\gamma,M} \equiv -\frac{M}{\gamma}\frac{\partial \gamma(M,p)}{\partial M}.$$

This elasticity always lies between zero and one. It is weakly decreasing in p, starting at one when $p = 0$ and falling to zero when $p = 1$. Therefore, money injections have proportionately larger effects on the exchange rate when the central bank is not credible.

As long as $p > 0$, money injections raise output. Moreover, since $\gamma(M, p)$ is also increasing in p, we conclude that the benefit of increasing money rises with p.[9]

We now must compare the benefit of a monetary injection with its inflation cost. Substituting the expression for e_1^b from (11) into the cost expression, (7), yields:

$$\Pi^{cost}(M; p) = \frac{\alpha}{2}\left(\gamma(M; p)^{-1} - 1\right)^2.$$

This cost term is also increasing in M, with the marginal cost highest when $p = 0$, and zero when $p = 1$.[10]

Combining costs and benefits we conclude that *in the horizontal region, the central bank will inject* $M \geq \underline{M}$. The inequality is strict in all cases other than $p = 0$. M is increasing in p, and is equal to its maximum value when $p = 1$.

3.4 Vertical View

With the horizontal case as a reference, we turn now to the vertical view of crises. Using the investment expression (3), we can construct aggregate consumption in the vertical region:

$$C^V = \left(\frac{A + a}{2}\right) k + w^n \frac{\Delta}{1 + i_1^*} + y^c. \tag{14}$$

[9] Differentiating this benefit once more with respect to p, we find that,

$$\frac{\partial}{\partial p}\left(\frac{\partial C^H}{\partial M}\right) = \frac{\Delta}{2}\frac{\partial \gamma}{\partial p} - \frac{\Delta\gamma}{2}\frac{\partial \epsilon_{\gamma,M}}{\partial p}.$$

Since, $\frac{\partial \gamma}{\partial p} > 0$, and $\frac{\partial \epsilon_{\gamma,M}}{\partial p} < 0$, the marginal benefit is increasing in p.

[10] The marginal cost is $\alpha(\gamma(M; p)^{-1} - 1)\frac{\epsilon(\gamma,M)}{M\gamma(M;p)}$. This is weakly positive since $\gamma^{-1} \geq 1$ and $\epsilon(\gamma, M) \geq 0$. It is also decreasing in p, since γ is increasing in p, while the elasticity term is decreasing in p.

From this expression, we reach a conclusion that contrasts starkly with the horizontal case: Expansionary monetary policy has no effect on aggregate consumption. The economy has a shortage of international liquidity, so reallocating domestic liquidity has no real effect.

Given this lack of effectiveness, the central bank turns its attention to an inflation target. Since the exchange rate depreciates in the b-state, and the central bank takes this to be costly, its optimal response is to contract money supply and support the exchange rate.

To see this, note that the objective of the central bank in the vertical region boils down to,

$$\max_{M} -\frac{\alpha}{2}\left(\frac{e_1^b(M)}{1+i_1^*}-1\right)^2. \tag{15}$$

In response to a shock that may raise $e_1^b > 1+i_1^*$, the central bank will choose monetary policy to maintain the exchange rate at $1+i_1^*$. Now recall that:

$$e_1^b = \frac{1+i_1^d}{\gamma(M;p)}. \tag{16}$$

Market clearing at date 1 results in the domestic dollar rate of,

$$1+i_1^d = (1+i_1^*)\left(\frac{ak+M\gamma(M;p)}{w^n}\right) > 1+i_1^*. \tag{17}$$

Equations (16) and (17) yield an expression for e_1^b which is increasing with respect to M:

$$e_1^b = (1+i_1^*)\left(\frac{ak\gamma(M;p)^{-1}+M}{w^n}\right).$$

We are now ready to establish the main proposition of this section. Let M^{nc} be the solution to (15). Then,

Proposition 1 *In the vertical region, the central bank chooses to tighten domestic liquidity ($M^{nc} < \underline{M}$). This restricts demand for international liquidity, causing i_1^d to fall towards i_1^*, and defends the date 1 exchange rate.*

Panels (a) and (b) in Figure 3 summarize the differences between the horizontal and vertical views. Note that in their downward sloping segments, demands are equal to $(ak + E[M/e_2])/(1+i_1^d)$.

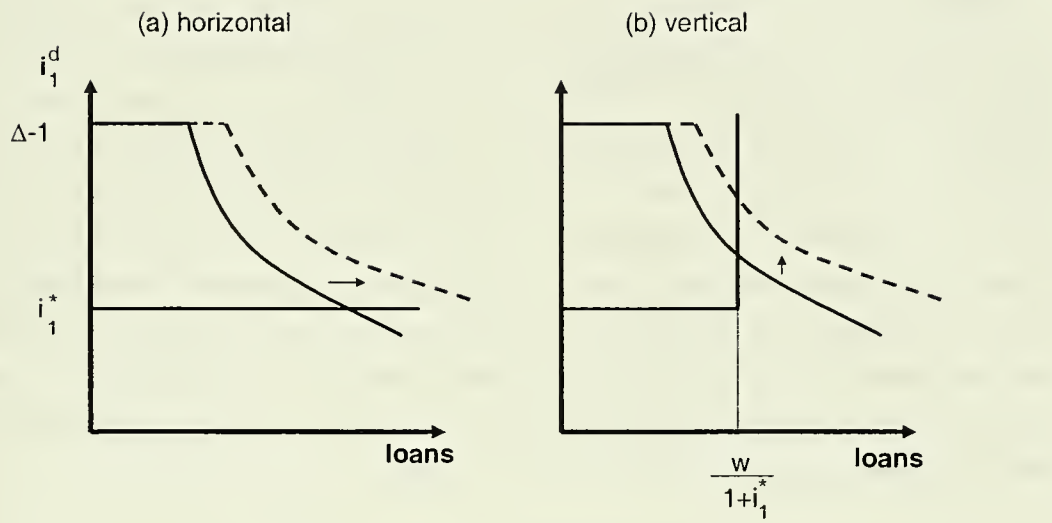

Figure 3: Domestic liquidity expansion

In the horizontal case, the increase in domestic liquidity caused by expanding monetary policy raises date 1 investment, leaving i_1^d unaffected. In the vertical region, the same increase in domestic liquidity has *no effect* on equilibrium investment, and only raises i_1^d. The obvious date 1 policy conclusion in the vertical region is to contract rather than expand monetary policy.[11]

4 Optimal Monetary Rule

Now we show that the date 1 discretionary monetary policy is ex-ante suboptimal. With a date 0 commitment to a state-contingent date 1 policy, the central bank does better by relaxing monetary policy more than it is inclined to do during a crisis. The gap between the commitment and the discretionary solutions occurs because central bank interventions

[11] One can introduce speculative attack-type effects by letting the probabilities of the different scenarios change with the level of M/T. Our basic message is unaffected by these considerations, although if the speculative effects are sufficiently strong so that M/e_1 falls with an expansionary monetary policy, the incentive to contract monetary policy will be enhanced. In extreme cases the latter may become the policy of choice even in the horizontal environment.

affect i_1^d. Expectations about this price turn out to be central in determining firms' financing and investment decisions at date 0.

In order to avoid confusion, it is important to note here that the commitment problem we discuss is around policies that affect the private sector's investment and borrowing decisions. We are not concerned directly with the standard inflationary bias emphasized in the inflation-credibility literature, a-la Barro and Gordon (1983), and we make assumptions such that this bias does not arise. This does not mean that inflation-credibility issues are irrelevant in our setting, because they restrict the policy options that a central bank has at date 1; this was one of our themes in Section 3. It simply means that aside from any effects on i_1^d, there is no incentive to surprise firms at date 1 with an inflation rate different from that announced at date 0. We use the words commitment and credibility to describe commitment with respect to i_1^d and credibility with respect to $e_2 = 1$, respectively. This section is primarily about commitment.

4.1 Private Sector Date 0 Decisions and i_1^d

At date 0, the private sector decides how much to borrow from foreign investors and how much real investment to undertake. The borrowing contracts specify an amount loaned to a domestic firm and a repayment at date 2, f^ω, contingent on the date 1 state $\omega \in \{b, g\}$. Since the funds raised from this loan are used in date 0 investment, and since foreign investors are risk neutral, the date 0 budget constraint is,

$$c(k) \leq \frac{1}{(1+i_0^*)(1+i_1^*)} \left((1-\pi) f^g + \pi f^b \right). \tag{18}$$

In the g-state at date 1, all firms make profits of,

$$Ak + (w - f^g) + \underline{M}.$$

In the b-state, one-half of the firms are distressed and they make profits of,

$$\left(\frac{ak + E[M/e_2]}{1+i_1^d} + \frac{w - f^b}{1+i_1^*} \right) \Delta,$$

while the other half are intact and make (expected) profits of,

$$Ak + (w - f^b) \frac{1+i_1^d}{1+i_1^*} + E\left[\frac{M}{e_2}\right].$$

Combining these expressions leads to the following problem for a firm at date 0,

PRIV:

$$\begin{aligned}
\max_{k,f^g,f^b} \quad & (1-\pi)(Ak + w - f^g + \underline{M}) \\
& + \pi\tfrac{1}{2}\left(\left(A + a\tfrac{\Delta}{1+i_1^d}\right)k + (\Delta + 1 + i_1^d)\tfrac{w-f^b}{1+i_1^*} + \left(1 + \tfrac{\Delta}{1+i_1^d}\right)E\left[\tfrac{M}{e_2}\right]\right) \\
s.t. \quad & f^g, f^b \leq w \\
& c(k) \leq \tfrac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b + (1-\pi)f^g).
\end{aligned}$$

Our technical assumptions (see the appendix) guarantee that $f^g = w$ and $f^b < w$. In other words, $f^g = w$ as long as increasing investment in k at date 0 is more profitable than investment in international markets. And $f^b < w$ as long as saving some resources to absorb the liquidity shocks at date 1 is more valuable than using all of those resources toward investment at date 0. It is apparent from the private program that i_1^d is the only equilibrium price that influences the date 0 decision. Let us study this connection more closely.

Since $f^g = w$, we simply need to consider the tradeoff between increasing f^b and reducing k. At date 0, building a marginally larger plant increases (expected) date 2 profits by,

$$(1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1+i_1^d}\right). \tag{19}$$

Building this larger plant requires the firm to raise an additional $c'(k)$ at date 0. Since this is all accommodated by increasing f^b, the cost to the firm is fewer resources to absorb the date 1 liquidity shock. Since the probability of a crisis is π, f^b must rise by,

$$\frac{c'(k)(1+i_0^*)(1+i_1^*)}{\pi}$$

and results in a fall in expected profits of,

$$\pi\left(\frac{\Delta + 1 + i_1^d}{2(1+i_1^*)}\right)\frac{c'(k)(1+i_0^*)(1+i_1^*)}{\pi},$$

that can be simplified to:

$$c'(k)(1+i_0^*)\left(\frac{\Delta + 1 + i_1^d}{2}\right). \tag{20}$$

The optimal private sector k equates (19) and (20). We note two comparative statics, and the conclusion that follows from them: (1) The benefit of building a larger plant size is decreasing in i_1^d; (2) The marginal cost of investing is increasing in i_1^d. For both reasons, k is decreasing with respect to i_1^d.

4.2 Date 0 Central Bank Problem in the Vertical Region

Let us now turn to the central bank's policy choice at date 0 to establish that it is optimal for the central bank to commit to a looser monetary policy during crises than is indicated by the discretionary solution of Proposition 1.

We show this in two steps. First, focusing purely on maximizing the value of date 2 (aggregate) consumption, we show that the private sector's date 0 choices are inefficient. More precisely, date 2 consumption is maximized at choices of (k, f^g, f^b) different from the private sector's choices. Appealing to the results of the previous subsection, we argue that date 1 monetary policy can affect and improve these choices. Second, we reintroduce the inflation cost of the previous section, and characterize the optimal policy choices.

4.2.1 Consumption Maximizing Choices

Let us first present the central bank's program to maximize date 2 aggregate consumption when it can directly choose (k, f^g, f^b). We show that this program differs from the private sector's program by eliminating i_1^d from **PRIV**. We substitute the market clearing condition for i_1^d from (8) into **PRIV**:

CENT:

$$\begin{array}{ll} \max_{k,f^g,f^b} & (1-\pi)(Ak+w-f^g)+\pi\left(\frac{w-f^b}{1+i_1^*}\Delta+\frac{A+a}{2}k\right) \\ s.t. & f^g, f^b \leq w \\ & c(k) \leq \frac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b+(1-\pi)f^g). \end{array}$$

The tradeoff between increasing k versus f^b is very different here than in **PRIV**. The benefit of increasing plant size is,

$$(1-\pi)A+\pi\frac{1}{2}(A+a).$$

For $i_1^d < \Delta - 1$, this benefit is strictly lower than the private sector's computation. On the cost side, borrowing more to build this plant costs,

$$c'(k)(1+i_0^*)\Delta.$$

For $i_1^d < \Delta - 1$, the cost lies strictly above the private sector's computation.

We conclude that as long as $i_1^d < \Delta - 1$ in the competitive equilibrium, if the central bank could choose (k, f^b) directly, its choices would differ from those of the private sector. The private sector over-invests at date 0, and underinsures against the date 1 liquidity shocks.

4.2.2 The Value of Central Bank Commitment

Since the central bank can affect i_1^d in its choice of M, it can use monetary policy to align the private sector's choices more closely with the consumption maximizing choices. Let us now characterize the optimal monetary rule from this perspective.

Define $U(k)$ as the value of the objective in **CENT**, a function of the date 0 choice of plant size. Recall that in the private sector's problem, k solves

$$c'(k)(1+i_0^*)\left(\frac{\Delta+1+i_1^d}{2}\right) = (1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1+i_1^d}\right)$$

which yields a strictly decreasing and continuous function $k(i_1^d)$ as a solution.

Since in **CENT**, the objective is linear while the constraint is convex, $U(k)$ is a concave function. Let k^* be the solution in **CENT**. We know that $U'(k) < 0$ as long as $k > k^*$. In other words, total output will increase if the value of this k is less than the private sector's value of k.

To find the monetary policy result, we first re-write the central bank's problem purely in terms of i_1^d (for $p > 0$):

$$\max_{i_1^d \in [\underline{i}_1^d, \Delta-1]} U(i_1^d) - \pi\Pi^{cost}(M(i_1^d)), \tag{21}$$

where, $\underline{i}_1^d$ is the value of i_1^d that prevails if the central bank chooses $M = 0$ at date 1 in the b-state.

The market clearing condition at date 1 in the b-state is,

$$1 + i_1^d = (1+i_1^*)\frac{ak + M\gamma(M;p)}{w^n}.$$

As long as $p > 0$, the range of $M\gamma(M;p)$ is the positive reals. Since $k(i_1^d)$ is decreasing and $w^n(i_1^d)$ is increasing, for every $i_1^d \in [\underline{i}_1^d, \Delta - 1]$ there exists a choice of M that will induce an equilibrium with that i_1^d. This allows us to write the central bank's program in (21) in terms of i_1^d.

By comparing the objectives in (21) with (15), we can see the value of commitment. For $i_1^d < \Delta - 1$, $U'(i_1^d) > 0$ in (21). However, in the central bank objective at date 1 there was no benefit from expanding money. In both programs, the cost term is the same. Thus:

Proposition 2 *The optimal monetary rule with commitment is $M^c > M^{nc}$.*

4.3 Inflation-credibility Problems and Optimal Monetary Policy

Inflation-target credibility also influences the extent to which a commitment to a monetary rule can be used to overcome the private sector's underinsurance problem.

Proposition 3 *Consider two economies indexed by $\hat{p}$ and p, where $\hat{p} > p$. Then the optimal monetary rule will yield $\hat{i}_1^d > i_1^d$.*

A more (inflation) credible central bank commits to act more aggressively at date 1; this results in a higher i_1^d and higher consumption. A higher p leads to a lower depreciation in e_1^b for each choice of i_1^d and to a date 2 exchange rate that is more insulated from the date 0 policy choice. This means that the cost of raising i^d in (21) falls, allowing for a higher i_1^d.

The formal argument is more involved because the program in (21) may not be concave, since $k(i_1^d)$ is not concave. Consider two economies where $\hat{p} > p$. We will first show that for any value of i_1^d:

$$\frac{\partial \Pi^{cost}(i_1^d; p)}{\partial i_1^d} > \frac{\partial \Pi^{cost}(i_1^d; \hat{p})}{\partial i_1^d}.$$

The marginal cost in the p-economy is,

$$\alpha \left(\frac{1 + i_1^d}{1 + i_1^*} \gamma(M; p)^{-1} - 1 \right) \frac{\partial (1 + i_1^d) \gamma(M; p)^{-1}}{\partial i_1^d}.$$

Consider evaluating this marginal cost for the same value of i_1^d for each of the two economies. If i_1^d is to be the same in the two economies, then from market clearing and since $\gamma(M; p) = \left(p + (1 - p) \min \left\{ 1, \frac{M}{\overline{M}} \right\} \right)$, it must be that $M\gamma(M; p)$ and $p(M - \underline{M})$ are constant across the two economies. This means that $\gamma(p) < \gamma(\hat{p})$ at the same value of i_1^d. Thus the first term in parentheses in the marginal cost expression is higher in the p-economy than in the $\hat{p}$-economy.

The second term reinforces this conclusion. It can be written as,

$$\gamma(M; p)^{-1} + (1 + i_1^d) \frac{\underline{M}}{(\gamma(M; p) M)^2} (1 - p) \frac{\partial M}{\partial i_1^d}.$$

By implicitly differentiating the market clearing condition, we can easily show that $\frac{\partial M}{\partial i_1^d}$ is higher in the p-economy than in the $\hat{p}$-economy. It requires a smaller change in nominal money to affect i_1^d when the central bank is more credible. Thus, we conclude that the marginal cost of raising i_1^d is uniformly lower in the $\hat{p}$-economy than in the p-economy.

Next, define $V(i_1^d; p)$ as the value of the objective in (21). Suppose in contradiction to the proposition that $\hat{i}_1^d < i_1^d$. Then, since i_1^d and $\hat{i}_1^d$ are maximizing choices for each of these economies respectively,

$$\begin{aligned} V(\hat{i}_1^d; \hat{p}) - V(i_1^d; \hat{p}) &= \int_{\hat{i}_1^d}^{i_1^d} \left(\pi \frac{\partial \Pi^{cost}(i_1^d; \hat{p})}{\partial i_1^d}(x) - U'(x; \hat{p}) \right) dx \geq 0 \\ V(\hat{i}_1^d; p) - V(i_1^d; p) &= \int_{\hat{i}_1^d}^{i_1^d} \left(\pi \frac{\partial \Pi^{cost}(i_1^d; p)}{\partial i_1^d}(x) - U'(x; p) \right) dx \leq 0. \end{aligned}$$

Since the marginal benefit of increasing i_1^d is independent of p, it must be that $U'(x;p) = U'(x;\hat{p})$. However, since the marginal cost of raising i_1^d is lower in the $\hat{p}$-economy, these two inequalities can hold only if $\hat{i}_1^d > i_1^d$. **QED**

5 Constrained Monetary Regimes

There are limits to implementing counter-cyclical monetary policy. We have highlighted three reasons why monetary policy may be unable to solve the private underinsurance problem:[12]

1. Time inconsistency of the optimal policy.
2. Limited inflation-target credibility.
3. Limited domestic financial underdevelopment.

We discussed the first two of these factors explicitly in the previous sections. The third stems from the fact that, in our model, limited domestic collateral is the source of the underinsurance problem. It can be shown (see Caballero and Krishnamurthy 2000b), that as the fraction of capital counted as domestic collateral falls, i_1^d falls. Informally, if in the market clearing condition of (17), the domestic liquidity of ak is reduced to λak $(\lambda < 1)$, i_1^d falls.[13] It follows that the cost of achieving any given level of i_1^d is higher in an economy with lower domestic financial development, because the central bank has to inject more M and thus depreciate e_1 further. So, the central bank opts for a lower i_1^d in the program (21), leaving a larger share of the underinsurance problem unresolved.

Regardless of the reason for such limits, the issue we address in this section is whether it is possible to reduce the costs of losing access to an effective countercyclical monetary policy. Our analysis points at a "silver-lining" for these constrained systems: Recognizing that the cost of losing monetary policy is in the date 0 decisions of the private sector, as opposed to the date 1 inflexibility of the central bank often emphasized in the literature,

[12] A fourth possibility, extensively discussed in the international economics literature, occurs when substantial amounts of private debt are dollar denominated. This can be thought of as another form of domestic financial underdevelopment. In this case, rather than lowering interest rates, the output maximizing policy may be defending the exchange rate. See, e.g., Aghion et al (2000), Gertler et al. (2001), Cespedes et al. (2000), and Christiano et al. (2000), for analysis of this balance sheet channel and arguments for and against the contractionary effects of currency depreciations.

[13] A more complete argument requires us to check that the effect of λ on date 0 decisions does not overturn this conclusion. See Caballero and Krishnamurthy (2000b) for the details.

leads to a natural set of policy options. The central bank can institute measures aimed directly at correcting the underinsurance problem of the private sector at date 0. We show that taxing capital inflows at date 0 is one such measure.

Recall that the problem induced by not being able to commit to expand credit at date 1 is that $\Delta - (1 + i_1^d)$ remains high. Thus the return to hoarding international liquidity until date 1 remains undervalued. Of course, this undervaluation arises only in the vertical region, as the aggregate international liquidity constraint does not bind in the horizontal region.

In our environment, there are two obvious ex-ante policy measures that can deal with the underinsurance problem: capital inflows taxation during normal times (date 0), and international liquidity requirements at date 0. Let us return to the analysis of the previous section and characterize the relationship between the optimal ex-ante tax and i_1^d.

The first order condition in **CENT** is,

$$c'(k^{CENT})(1 + i_0^*)\Delta = (1 - \pi)A + \pi\frac{1}{2}(A + a),$$

whereas that for the private sector sets (19) equal to (20).

Aligning the date 0 private and consumption-maximizing incentives is a matter of choosing a tax/transfer policy. Suppose that the central bank levies a tax τ per unit of k, which is returned to firms in a lump sum fashion. Then the first order condition for the private sector becomes:

$$c'(k)(1 + i_0^*)\frac{\Delta + 1 + i_1^d}{2} = (1 - \pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1 + i_1^d}\right) - \tau$$

Choosing τ to align the private and central-bank incentives yields:

Proposition 4 *For any equilibrium level of $i_{1,\tau}^d$, the optimal tax solves,*

$$\tau(i_{1,\tau}^d) = \frac{1}{2}\left(\frac{a}{1 + i_{1,\tau}^d} + c'(k^{CENT})(1 + i_0^*)\right)(\Delta - (1 + i_{1,\tau}^d)).$$

If there is enough domestic liquidity during crises so that in the absence of taxes $i_1^d = \Delta - 1$, there is no reason for intervention at date 0. In other cases, for example if p is small, the optimal tax is positive.

Note also that the same result could be achieved via a contingent liquidity requirement. The tax solution gives the private sector incentives to choose the efficient k, thus resulting in the efficient $w - f^b$. Alternatively, the central bank could directly mandate that each firm preserve international liquidity for the date 1 crisis-state, so that the efficient level of $w - f^b$ is realized.

In practice, taxes come with their own sets of distortions: deadweight costs of taxation, costs of enforcement, evasion, etc. However, the important point to recognize is that, in the vertical framework, the cost of losing monetary policy is *not* lack of flexibility at date 1. Rather, it is in the underinsurance by the private sector at date 0. In this sense, the costs of having to enforce capital controls may be seen as a direct cost of losing monetary policy.

6 Final Remarks

Much of the discussion of monetary policy and exchange rate systems focuses on the issue of inflation credibility. This is largely an historical artifact, since inflation stabilization had been the dominant concern of emerging economies for many decades. Today, as many emerging economies go beyond this, the central concern has shifted to avoiding external financial crises. This is the starting point of our paper. In our analysis, central bank actions should be directed toward correcting the chronic tendency of emerging economies to underinsure against external shocks. Moreover, we argue that the standard inflation-stabilization concern can be a serious obstacle to implementing optimal monetary policy, because it creates a time-consistency problem. Central banks should follow counter-cyclical monetary policy; if they are unable to commit to this policy, inflation concerns will lead them to act in the opposite way.

This change in perspective also has relevance for evaluation of other government policies. Pro-actively managing international reserves may result in benefits in our framework. Since international reserves are a form of international liquidity and the private sector carries too little international liquidity into crises, the central bank has a role to play by carrying reserves in place of the private sector. However, the inflation stabilization concern may also undercut this policy. Injecting reserves during a crisis has the twin benefits of relaxing the international financial constraint and lowering i^d. Hence the exchange rate is stabilized. Relaxing the constraint is beneficial but the effect on the private sector's own insurance incentives is not, for reasons akin to those we discussed in the context of monetary policy. Ex-post, the central bank will ignore the incentive effect and inject more reserves than it would have chosen ex-ante.

Reserves management and monetary policy are complementary policy tools in this context. If the central bank is credible, it should expand money at the same time that it injects reserves. This raises i^d and can fully offset the incentive effect of the reserves injection. Although few emerging economies have the luxury of following a counter-cyclical monetary policy, this observation underscores its value.

In our environment, monetary policy without monetary frictions is simply a reallocation device. A fiscal policy that transfers domestic liquidity from consumers to the corporate sector will achieve the same end. While, in practice, fiscal policy may be less flexible than monetary policy, this interpretation sheds light on the workings of fiscal policy in a vertical framework. On the one hand, if the fiscal instrument can be targeted efficiently toward distressed firms, then it can play a useful role. On the other hand, an unselective fiscal expansion designed to boost aggregate demand may be harmful, because it lowers the distressed firms' collateral by raising i^d without the compensating benefit that a selective fiscal gift would bring to these firms. In our vertical model, untargeted fiscal policy crowds out private investment one-for-one. Furthermore, by raising i^d, this policy depreciates the exchange rate. The standard Mundell-Fleming logic of fiscal policy and its impact on the exchange rate is turned on its head.[14]

There are many caveats about a stylized model like ours. One worth mentioning in concluding, is our assumption that all crises are either vertical or horizontal. Of course, in practice, crises are mostly "diagonal," but our novelty is in the non-horizontal ingredient and the limited substitutability between domestic and international liquidity during crises. More interestingly, crises build up, going first through a horizontal phase in which domestic financial conditions tighten and external borrowing becomes gradually more expensive, then falling into a sharp vertical sudden stop phase. A central question for policymakers in this context is how to conduct monetary policy at the early stages of the crisis, when supply is still horizontal but there is a concern that events may lead to a binding international liquidity constraint. At this stage, tightening monetary policy will destroy financially constrained projects but save international liquidity for the vertical event. We conjecture that this trade-off can be analyzed in terms similar to those we have used throughout: If the commitment to an aggressive countercyclical monetary policy in case of a vertical event is credible, then there is little need to tighten during the horizontal phase. But if the commitment is not credible or feasible, then the appropriate response is to tighten during the early phase in order to protect international liquidity, very much as taxing capital flows at date 0 was advisable in our simplified model when there was no commitment. In fact, the costs in terms of the additional financial distress imposed on the domestic private sector is, to a large extent, comparable in nature to the costs of the ex-ante measures we already discussed.

[14] See Caballero and Krishnamurthy (2002).

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A Appendix

The financial frictions of the model are embodied in the following two assumptions:

Assumption 1 (International Collateral)
Foreigners lend to domestic firms only against the backing of w. Domestic agents lend against both w and ak.

Assumption 2 (Domestic Collateral)
A domestic lender can only be sure that a firm will produce ak units of goods at date 2. Any excess production based on physical reinvestment at date 1 is neither observable nor verifiable.

One last assumption is required to rule out date 0 insurance arrangments that transfer resources from distressed firms to intact firms.

Assumption 3 (Non-observability of Production Shock)
The production shock at date 1 is idiosyncratic. The identity of firms receiving the shock is private information.

In Caballero and Krishnamurthy (2001c), we solve the mechanism design problem associated with these financing and informational constraints and show that it corresponds to the one in **CENT**. We also discuss how a banking arrangement in principle may get around the private information constraint, but that it will be very fragile.

Consider next the technical assumptions on parameters that we have used. The program in **CENT** is,

CENT:

$$\begin{aligned} \max_{k,f^g,f^b} \quad & (1-\pi)(Ak+w-f^g)+\pi\left(\tfrac{w-f^b}{1+i_1^*}\Delta+\tfrac{A+a}{2}k\right) \\ s.t. \quad & f^g, f^b \leq w \\ & c(k) \leq \tfrac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b+(1-\pi)f^g). \end{aligned}$$

First, we require that $w = f^g$ in this program, or that the return to investing domestically exceeds that of investing abroad:

Assumption 4 (High Investment Return)

$$(1-\pi)A+\pi\frac{A+a}{2} \geq c'\left(\frac{w}{(1+i_0^*)(1+i_1^*)}\right)(1+i_0^*)(1+i_1^*).$$

Second, we require that the solution features some insurance against the b-state, so that $f^b < w$.

Assumption 5 (High Return to Insuring)

$$c'\left(\frac{w}{(1+i_0^*)(1+i_1^*)}\right)(1+i_0^*)\Delta \geq (1-\pi)A+\pi\frac{A+a}{2}.$$

Finally, we require that equilibrium, with no central bank intervention, places us in the vertical region, or,

$$1 + i_1^* < 1 + i_1^d < \Delta.$$

The first order condition for the program in **PRIV** is,

$$c'(k)(1 + i_0^*)\frac{\Delta + 1 + i_1^d}{2} = (1 - \pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1 + i_1^d}\right).$$

Denote the solution to this equation as $k(i_1^d)$. Then the largest value of k is attained when $i_1^d = i_1^*$, and the smallest value when $i_1^d = \Delta - 1$. Using this knowledge as well as the market clearing condition leads to:

Assumption 6 (Equilibrium in Vertical Region)

$$\begin{aligned} \frac{\pi a k(i_1^*)}{w - (1 + i_0^*)(1 + i_1^*)c(k(i_1^*))} &< \frac{\Delta}{1 + i_1 *} \\ \frac{\pi a k(\Delta - 1)}{w - (1 + i_0^*)(1 + i_1^*)c(k(\Delta - 1))} &> 1 \end{aligned}$$

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